Semester: 6-CBCS 2018
Subject: DESIGN OF MACHINE ELEMENTS II (18ME62)
Faculty: Mr Manikandan

Date: 21 May 2021
Time: 09:00 AM - 10:00 AM
Max Marks: 50

Instructions to Students :

1. Answer all the questions
2. Use of Machine design data handbook is permitted

Answer All Questions

Q.No		Marks	CO	PO	BT/CL
1	For a flat belt drive, the following data are given: Speed of the motor = 1500 rpm Speed of driven pulley = 500 rpm Power to be transmitted = 9 kW Weight density of leather = 9.8 kN/m^3 Smaller pulley diameter to belt thickness ratio = 36 Center distance = 2.1 m Factor of safety = 10 Ultimate strength of belt material = 24 MPa Velocity of belt drive = 16 m/s Coefficient of friction = 0.36 Design the belt	25	CO2	PO1	L3
2	Select a V belt to connect a 15 kW, 2880 rpm motor to a centrifugal pump, running at approximately 2400 rpm, for a service of 18 hours per day. The centre distance should be approximately 400 mm. Assume the pitch diameter of driving pulley as 125 mm	25	CO2	PO1	L3

Solutions

Q.No 1

Data :

$$N = 9\text{ kW} ; n_1 = 1500\text{ rpm} ; n_2 = 500\text{ rpm} ; v = 16\text{ m/sec}$$

$$\text{Load factor} = 1.2 ; w = 9.8\text{ kN/m}^3 = \frac{9.8 \times 1000}{1000^3} = 9.8 \times 10^{-6}\text{ N/mm}^3$$

$$\frac{d}{t} = \frac{d_1}{t} = 36 ; \text{factor of safety, } n = 10 ; \sigma_u = 24\text{ MPa} = 24\text{ N/mm}^2$$

$$C = 2.1\text{ m} = 2100\text{ mm} ; \mu = 0.36$$

(i) Diameter of pulley and thickness of belt

$$\text{velocity, } v = \frac{\pi(d_1 + t)n_1}{60{,}000} = \frac{\pi\left(d_1 + \frac{d_1}{36}\right).n_1}{60{,}000} = \frac{\pi d_1 n_1\left(1 + \frac{1}{36}\right)}{60{,}000} \quad \left(\because \frac{d_1}{t} = 36\right)$$

$$\text{ie., } 16 = \frac{\pi \times d_1 \times 1500 \times \left(1 + \frac{1}{36}\right)}{60{,}000}$$

$\therefore$ Diameter of smaller pulley $d_1 = d = 198.2$mm

$$\frac{d}{t} = 36 \quad \text{[Given]}$$

$$\text{ie., } t = \frac{d}{36} = \frac{198.2}{36} = 5.5\text{ mm}$$

$\therefore$ Thickness of belt, $t = 5.5$ mm

$$\text{Now, } n_1(d_1 + t) = n_2(d_2 + t)$$

$$\text{ie., } 1500\,(198.2 + 5.5) = 500\,(d_2 + 5.5)$$

$\therefore$ Diameter of larger pulley, $d_2 = D = 605.6$ mm

(iii) Centrifugal stress

$$\sigma_c = \frac{wv^2}{g} \times 10^6 = \frac{9.8 \times 10^{-6} \times 16^2}{9810} \times 10^6 = 0.256 \text{ N/mm}^2$$

---- 21.3(b)/14.3(f)

(iii) Capacity

Assume it is an open belt drive

Capacity $= e^{\mu\theta_s}$ ($\therefore$ μ is same for both smaller and larger pulleys)

For open belt drive, $\theta_s = \pi - \left\{2\sin^{-1}\left(\frac{D-d}{2C}\right)\right\}\frac{\pi}{180}$ ---- 21.10(b)/14.1(a)

$$= \pi - \left\{2\sin^{-1}\left(\frac{605.6-198.2}{2\times 2100}\right)\right\}\cdot\frac{\pi}{180} = 2.9473 \text{ radians} = 168.867^\circ$$

$$\therefore e^{\mu\theta_s} = e^{0.36\times 2.9473} = 2.89 = e^{\mu\theta}$$

(iv) Constant

$$k = \frac{e^{\mu\theta}-1}{e^{\mu\theta}} = \frac{2.89-1}{2.89} = 0.654$$

(v) Width of belt

Allowable stress in the belt, $\sigma_1 = \frac{\sigma_u}{\text{Factor of safety}} = \frac{24}{10} = 2.4 \text{ N/mm}^2$

Power transmitted per mm² $= \frac{(\sigma_1 - \sigma_c)kv}{1000}$ ---- 21.4(a)/14.6(a)

$$= \frac{(2.4-0.256)0.654\times 16}{1000} = 0.022435 \text{ kW}$$

$\therefore$ Area of cross-section of belt, $A = \frac{\text{Total power}}{\text{Power per } mm^2} \times \text{Load factor}$

$$= \frac{9}{0.022435} \times 1.2 = 481.4 \text{ mm}^2$$

Also, $A = b \times t$

ie., $481.4 = b \times 5.5$

$\therefore$ Width of belt, $b = 87.5$ mm

(vi) Length of open belt

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\theta_L + d\theta_s)$$ ---- 21.7/14.2(b)

$$\theta_L = \pi + \left\{2\sin^{-1}\left(\frac{D-d}{2C}\right)\right\}\frac{\pi}{180}$$ ---- 21.10(a)/14.1(b)

$$= \pi + \left\{2\sin^{-1}\left(\frac{605.6-198.2}{2\times 2100}\right)\right\}\frac{\pi}{180} = 3.336 \text{ radians}$$

$$L = \sqrt{4\times 2100^2 - (605.6-198.2)^2} + \frac{1}{2}[605.6 \times 3.336 + 198.2 \times 2.9473]$$

$\therefore$ Length of open belt, $L = 5482.4$ mm

(viii) Initial tension in the belt

$$2\sqrt{T_0} = \sqrt{T_1} + \sqrt{T_2}$$ ---- 21.12/14.8

$$\frac{\sigma_1 - \sigma_c}{\sigma_2 - \sigma_c} = e^{\mu\theta}$$ ---- 21.3(a)/14.3(d)

ie., $\frac{2.4-0.256}{\sigma_2 - 0.256} = 2.89$

$\therefore \sigma_2 = 0.998 \text{ N/mm}^2$

$\therefore$ Tension on tight side, $T_1 = \sigma_1 A = 2.4 \times 481.4 = 1155.36$ N

Tension on slack side, $T_2 = \sigma_2 A = 0.998 \times 481.4 = 480.4$ N

ie., $2\sqrt{T_0} = \sqrt{1155.36} + \sqrt{480.4}$

$\therefore$ Initial tension, $T_0 = 781.44$ N

Q.No. 2

$N = 15$ kW; $n_1 = 2880$ rpm ; $n_2 = 2400$ rpm ; $C = 400$ mm ; $d_1 = 125$ mm

Solution :

(i) **Diameter of larger pulley**

$$n_1 d_1 = n_2 d_2$$

i.e., $2880 \times 125 = 2400 \times d_2$

$\therefore$ Diameter of larger pulley $d_2 = D = 150$ mm.

(ii) **Select the cross-section of belt**

Equivalent pitch diameter of smaller pulley $d_e = d_p F_b$ ----- 21.35/Table 14.18

where $d_p = d_1 = 125$

$$\frac{n_1}{n_2} = \frac{2880}{2400} = 1.2$$

From Table 21.25/14.15 for $\frac{n_1}{n_2} = 1.2$, Smaller diameter factor $F_b = 1.07$

$\therefore$ Equivalent pitch diameter of smaller pullay $d_e = 125 \times 1.07 = 133.75$ mm

From page 307 (Old DDHB); page 21.13 (New DDHB)/Table 14.18, the cross-section of the belt selected corresponding to the equaivalent pitch diameter $d_e = 133.75$ mm is 'B' cross section belt.

(iii) **Velocity**

$$v = \frac{\pi d_1 n_1}{60000} = \frac{\pi \times 125 \times 2880}{60000} = 18.85 \text{ m/sec.}$$

(iv) **Power capacity or Power rating of single V-belt**

For 'B' Cross-section belt

$$N^* = v\left(\frac{0.79}{v^{0.09}} - \frac{51.33}{d_e} - \frac{1.31v^2}{10^4}\right) \quad \text{----- 21.31/Table 14.18}$$

$$= 18.85\left(\frac{0.79}{18.85^{0.09}} - \frac{51.33}{133.75} - \frac{1.31 \times 18.85^2}{10^4}\right) = 3.32 \text{ kW}$$

(v) **Number of belts**

$$\text{Number of v-belts } i = \frac{NF_a}{N^* F_c . F_d} \quad \text{----- 21.36/14.14}$$

From Table 21.28/14.19 for the driven mechanism centrifugal pump and a service of 18 hrs per day

Load application factor or Correction factor for service $F_a = 1.2$

$$\text{Pitch length of belt } L = 2C + \frac{\pi}{2}(D + d) + \frac{(D - d)^2}{4C} \quad \text{----- 21.38/14.15(b)}$$

$$= 2 \times 400 + \frac{\pi}{2}(150 + 125) + \frac{(150 - 125)^2}{4 \times 400} = 1232.36 \text{ mm}$$

From Table 21.29/14.17, the nearest standard value of nominal pitch length for the selected 'B' cross-ection belt $L = 1212$ mm. and Nominal inside length = 1168 mm.

From Table 21.27/14.20 for nominal inside length = 1168 mm and 'B' Cross-section belt

Correction factor for length $F_c = 0.87$

$$\text{Angle of contact } \theta = 2\cos^{-1}\left(\frac{D-d}{2c}\right) = 2\cos^{-1}\left(\frac{150-125}{2\times 400}\right) = 176.42^\circ$$

----- 21.45

$$= 2\cos^{-1}\left(\frac{150-125}{2\times 400}\right) = 176.42^\circ$$

From Table 21.26/14.21 for $\theta = 176.42^\circ$ and V-V belt (Assume) correction factor for angle of contact $F_d = 0.99$

$$\therefore\ i = \frac{15\times 1.2}{3.32\times 0.87\times 0.99} = 6.295$$

$\therefore$ Number of V- belts i = 7

(vi) Correct centre distance

$$C = \frac{L}{4} - \frac{\pi(D+d)}{8} + \sqrt{\left\{\frac{L}{4} - \frac{\pi(D+d)}{8}\right\}^2 - \frac{(D-d)^2}{8}}$$

----- 21.39 /14.15(a)

$$= \frac{1212}{4} - \frac{\pi(150+125)}{8} + \sqrt{\left\{\frac{1212}{4} - \frac{\pi(150+125)}{8}\right\}^2 - \frac{(150-125)^2}{8}}$$

$= 389.815$ mm

$\therefore$ Correct centre distance C = 389.815 mm

Specification of V Belt

B-1168

From table 21.23, for 'B' cross section belt

Nominal top width W = 17 mm

Nominal thickness T = 11 mm